Problem 7.16

Because the transistors are matched with equal areas except $Q_2$ which has an area of 2, we have $I_{C4} = 2I_{C3}$ and $I_{C1} = I_{C2}$.

Also we have

$$I_{\text{ref}} = \frac{(V_{CC} - 1.2)}{R_{\text{ref}}} = I_{C1} + \frac{I_{C3}}{\beta} + \frac{I_{C4}}{\beta}$$

Furthermore at the collector of $Q_2$, we can write the current equation

$$\frac{I_{C1}}{\beta} + \frac{I_{C2}}{\beta} + I_{C2} = \frac{I_{C3}(\beta + 1)}{\beta} + \frac{I_{C4}(\beta + 1)}{\beta}$$

From these equations we eventually have

$$I_{C3} = I_{C4}/2 = \frac{\beta^2 + 2\beta}{3\beta^2 + 6\beta + 6} \times \frac{V_{CC} - 1.2}{R_{\text{ref}}} \approx \frac{I_{\text{ref}}}{3}$$
Problem 7.20

\[ I_{\text{ref}} = \frac{(V_{\text{CC}} - 0.6)}{R} = 1.44 \text{ mA} \]

\[ I_{C2\text{min}} = \frac{I_{\text{ref}}}{1 + 2/\beta} = \frac{1.44}{1 + 2/100} = 1.4117 \]
\[ I_{C2\text{max}} = \frac{I_{\text{ref}}}{1 + 2/\beta} = \frac{1.44}{1 + 2/200} = 1.4257 \]

Thus the percentage increase in \( I_{C2} \) is

\[ \frac{I_{C2\text{max}} - I_{C2\text{min}}}{I_{C2\text{min}}} \times 100\% = 0.995\% \]
Problem 7.37

For \( M_1 \) we have

\[
I_{D1} = \left( \frac{W_1}{L_1} \right) \frac{KP}{2} (V_{GS1} - V_{top})^2
\]

substituting values and solving for \( V_{GS1} \) we obtain \( V_{GS1} = -5 \) V. Similarly we obtain \( V_{GS3} = 5 \) V. Then we have

\[
R = (15 + V_{GS1} - V_{GS3})/(1 \text{ mA}) = 5 \text{ k}\Omega.
\]

Finally \( I_2 = I_{D1} (\frac{W_2}{W_1}) = 1 \text{ mA} \), and \( I_3 = I_{D1} (\frac{W_3}{W_1}) = 2 \text{ mA} \).
Problem 7.49

By symmetry, we conclude that $I_{CQ1} = I_{CQ2} = 5 \text{ mA}$. Then we have $r_{\pi 1} = r_{\pi 2} = \beta V_T / I_{CQ} = 1040 \Omega$. Also the differential input voltage is $v_d = v_{in}$. From Table 7.2 on page 450 in the book, we have

$$A_{vds} = \frac{v_{o2}}{v_d} = \frac{v_o}{v_{in}} = \frac{R_C \beta}{2[r_{\pi} + (\beta + 1)R_{EF}]}$$

$$= \frac{1000 \times 200}{2[1040 + 201 \times 20]} = 19.8$$

$$R_i = R_{id} = 2[r_{\pi} + (\beta + 1)R_{EF}] = 10.1 \text{ k\Omega}$$
Problem 7.73

The bias currents for $Q_1$ and $Q_2$ are $I_{CQ1} = I_{CQ4} \approx 10 \, \mu A$. Thus we have $I_{BQ1} = I_{BQ2} = (10 \, \mu A)/\beta = 50 \, nA$. The bias current of an op amp is the average of the input currents. Thus, we have $I_B = 50 \, nA$. 